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# The influence of anticrossing of exciton states on exciton relaxation in GaAs/AlGaAs double single quantum wells

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It is well known that an external steady electric field shifts the energy position of exciton levels in semiconductor quantum wells. One can choose the particular value of the applied electric field so that the energy positions of different exciton states from neighbouring quantum wells should coincide. The changing of resonant position of each "coinciding" exciton states has been studied both theoretically and experimentally [1]. It was shown that the interaction of these exciton states leads to the mixing of their wave functions and, consequently, modifies their properties.

First of all the mixing of exciton wave functions leads to the strong nonlinear dependencies of the exciton energy position on the applied electric field. Instead of simple crossing due to increasing of the electric field the exciton levels kind of repel of each other and have not any crossing at all. That is why one calls this effect anticrossing. As an example, the anticrossing of heavy holes is shown in Fig. 1 for the structure we used in the experimental part of our work. The anticrossing of the excitons displays absolutely the same behaviour [2]. In Fig. 1 it looks like the interacting particles just exchange their properties. It should really take place, as the calculation shows that the these particles exchange their wave functions [3].

The anticrossing of light hole and heavy hole exciton in GaAs/AlGaAs duble single quantum wells with well width of 80 Å and barrier width of 50 Å was investigated. Radiation with a duration of 150 fs from a tunable Ti-sapphire laser was used in a two beam arrangement to excite states of heavy and light excitons simultaneously and to observe a spectrally resolved four wave mixing (FWM) signal. The sample was located in an optical helium cryostat at a temperature of about 10 K. The FWM spectra with different time delay between two laser pulses were detected with an interval of 50 fs with a spectrometer and an OMA multichannel optical detector with a resolution of 0.1 meV.

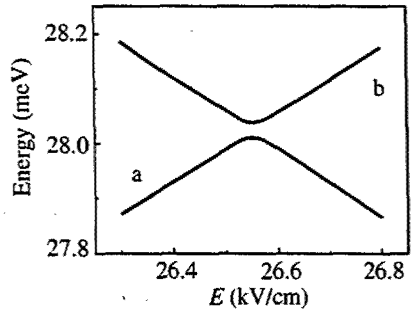


**Fig. 1.** The behaviour of energy position of the asymmetric ground heavy hole state (a) and the symmetric first excited heavy hole state (b) in the region of anticrossing.

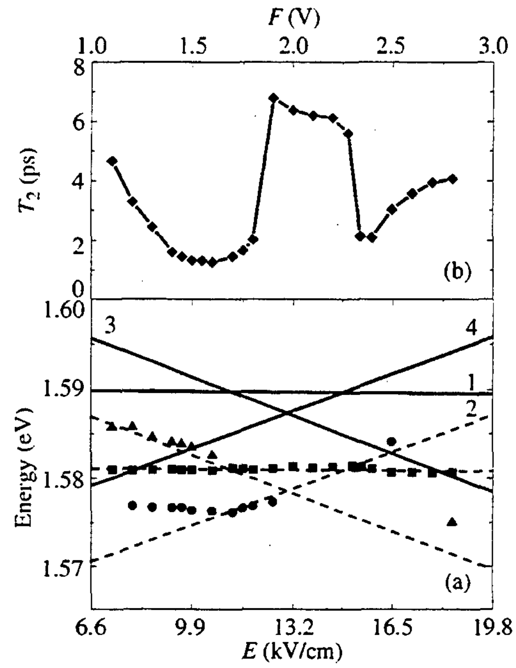


**Fig. 2.** (a) The energy positions of exciton lines we observed in the spectra of FWM signal for different values of experimental applied electric field ($F$) are indicated by open circle, square and up-triangle. The theoretical electron–hole transitions which correspond to observed excitons are shown by solid lines. See the text to get further explanation. (b) The dephasing time of light excitons 1 and 2 as a function of applied electric field $F$.

To get the theoretical energy position of electron–hole optical transitions we used the variational calculation [2]. The result of this calculation is shown in Fig. 2(a) by solid lines. One can see that there are four optical transitions in the region we investigated. The transition between the symmetrical electron state and the asymmetrical ground light hole state is indicated by 1; the asymmetrical electron state and the symmetrical ground light hole state 2; the symmetrical electron state and the asymmetrical first excited heavy hole state 3; the asymmetrical electron state and the asymmetrical ground heavy hole state 4 [4]. The transition 1 and 2 are the same transitions in the different quantum wells. The experimentally measured positions of excitons are shown by opened circles, squares and up-triangles in the same figure. The distance between the exciton and electron–hole transitions allows us to estimate the exciton binding energy. In our experimental condition we get the exciton binding energy of 8.8 meV.

The dependence of the dephasing time $T_2$ of the light hole excitons 1 and 2 on the applied electric field F are shown in Fig. 2(b). At first $T_2$ decreases and reaches its first minimum in the region of the anticrossing of the excitons 1 and 2 with exciton 4 ($T_2 = 1.3$ ps). Then $T_2$ restores its initial value ($T_2 = 6.5$ ps) and keeps it unchanging until the anticrossing with the exciton 3. After that $T_2$ again slowly restores its unperturbed value. The explanation of such behaviour is the following. The electron–hole transitions number 1 and 2 are the optically allowed, whereas the transitions number 3 and 4 are forbidden [4]. The dephasing time $T_2$ of the excitons 1 and 2 is much longer than $T_2$ is for the excitons 3 and 4. So, due

to the mixing of wave functions of the excitons 1 and 2 with optically forbidden states their dephasing time becomes shorter.

In conclusion it was found that the dephasing time $T_2$ of direct light hole excitons is decreased in 5 times by mixing its wave function with indirect heavy hole exciton wave function. The decreasing and restoring of light hole exciton dephasing time takes place two times for the values of external steady electric field from 1 V to 3 V. We hope this effect will be useful for the designing of new electro-optic devises.

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